



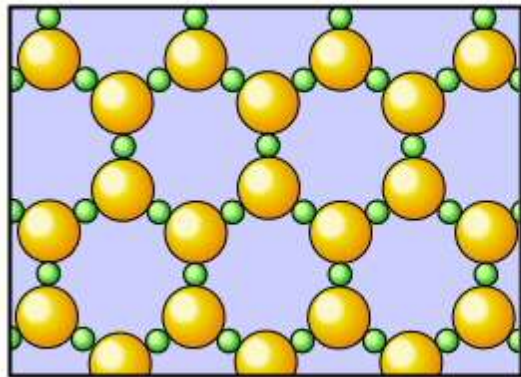
Atmospheric Moisture

Chapter 6

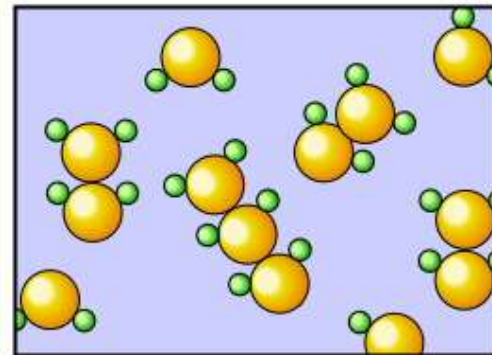
The Nature of Water: Commonplace: but Unique



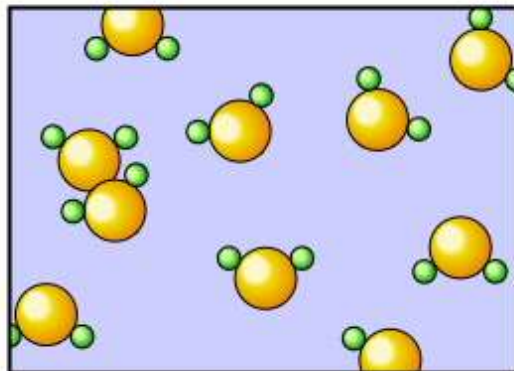
- Water Molecule H_2O
- Properties of Water
 - Surface Tension
 - A thin “skin” of molecules forms on the surface of liquid water causing it to “bead”
 - This surface tension allows for capillarity
 - Water can move up cracks in rocks, between soil and roots and stems
 - Universal Solvent
 - Heat Capacity, holds its temperature



**Ordered
Molecular
Structure of
Frozen Water**



**Semi-Ordered
Molecular
Structure of
Liquid Water**

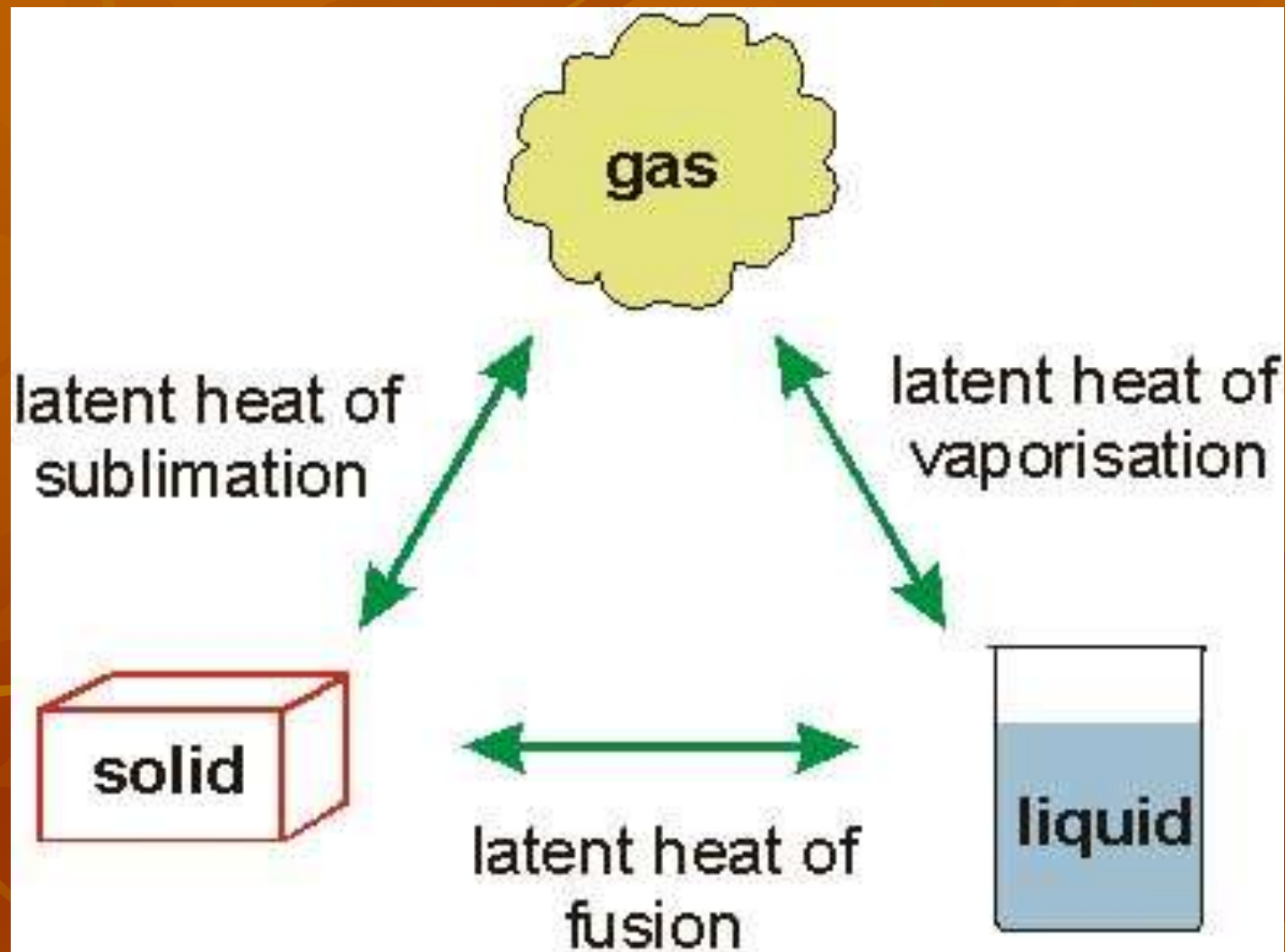


**Random
Molecular
Structure of
Vaporized Water**

Phase Changes of Water



- Evaporation— liquid to gaseous form
- Condensation— water vapor to liquid water
- Sublimation— gaseous to solid or solid to gaseous state
 - Each of these changes, latent heat is transferred

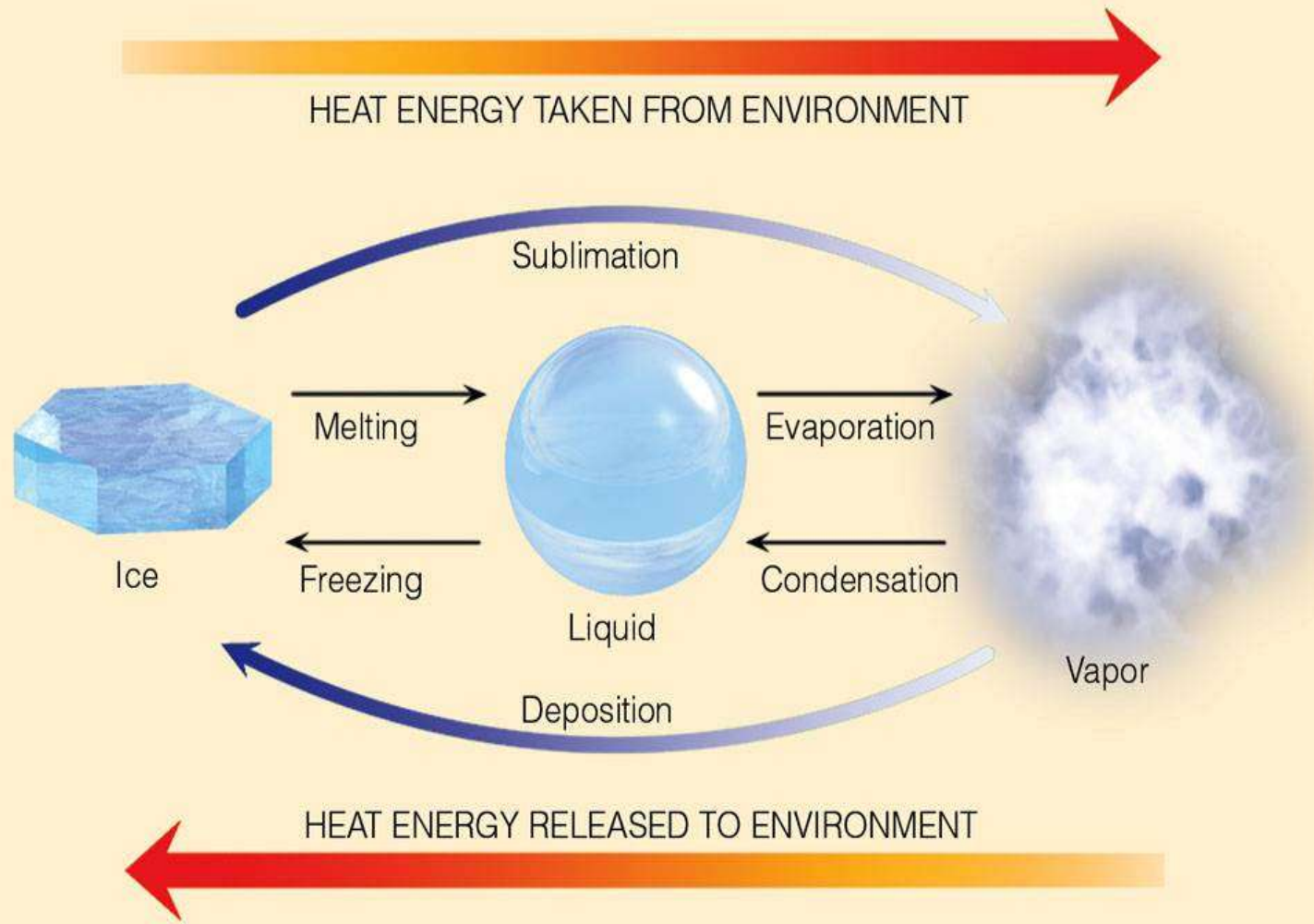


Phase Changes of Water

■ Latent Heat

- Latent heat of vaporization or evaporation – the energy required to vaporize liquid water -- cooling
- Latent heat of condensation – the energy released during condensation -- heating
- Latent heat of melting – the energy required to change ice to water

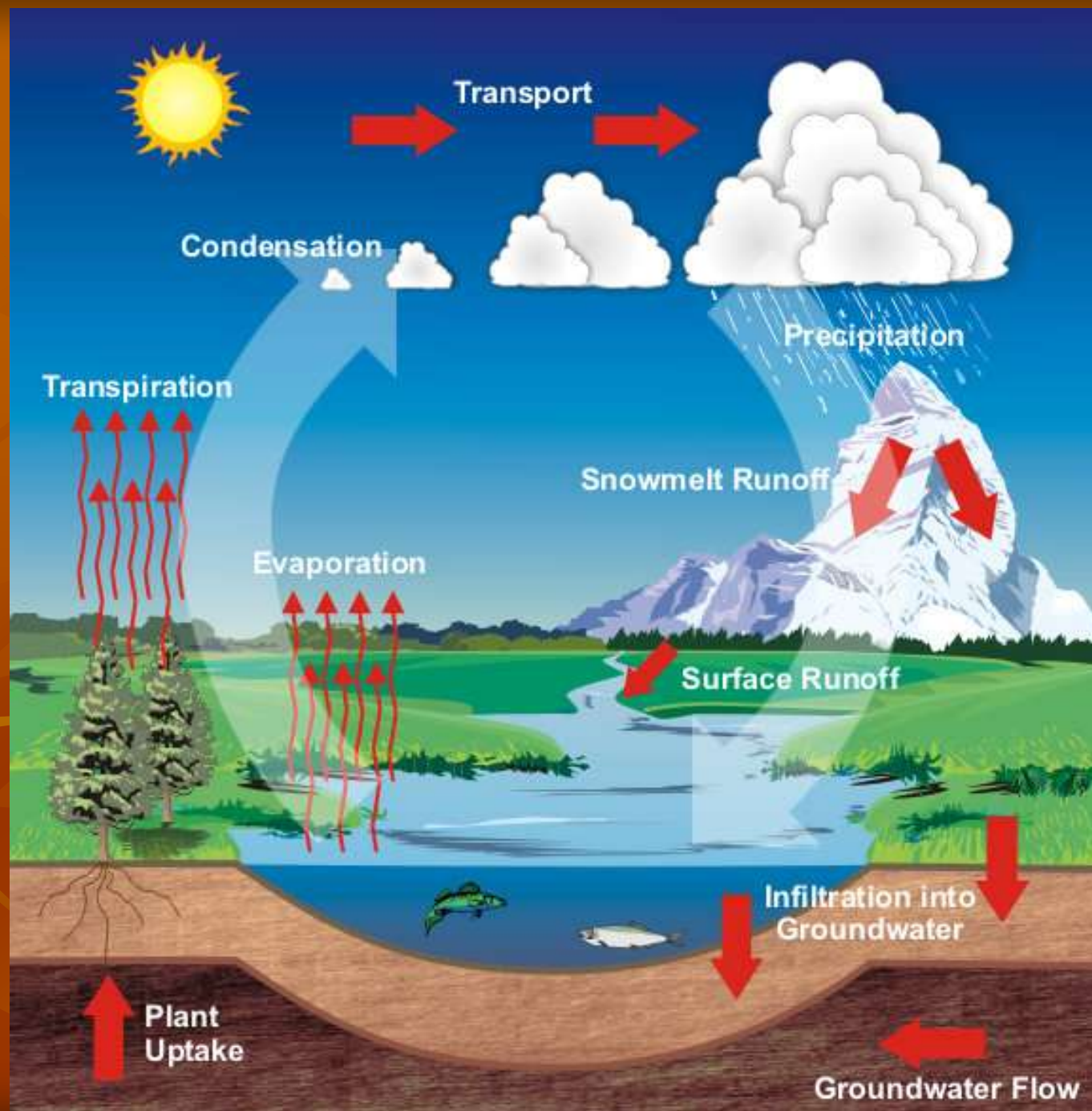




Water Vapor and Hydrologic Cycle



- Hydrologic Cycle
 - Water Vapor in the air, returns to the earth through precipitation, from the earth through streams, ground water and evaporation or evapotranspiration returns to the oceans and the air to start again.



Evaporation

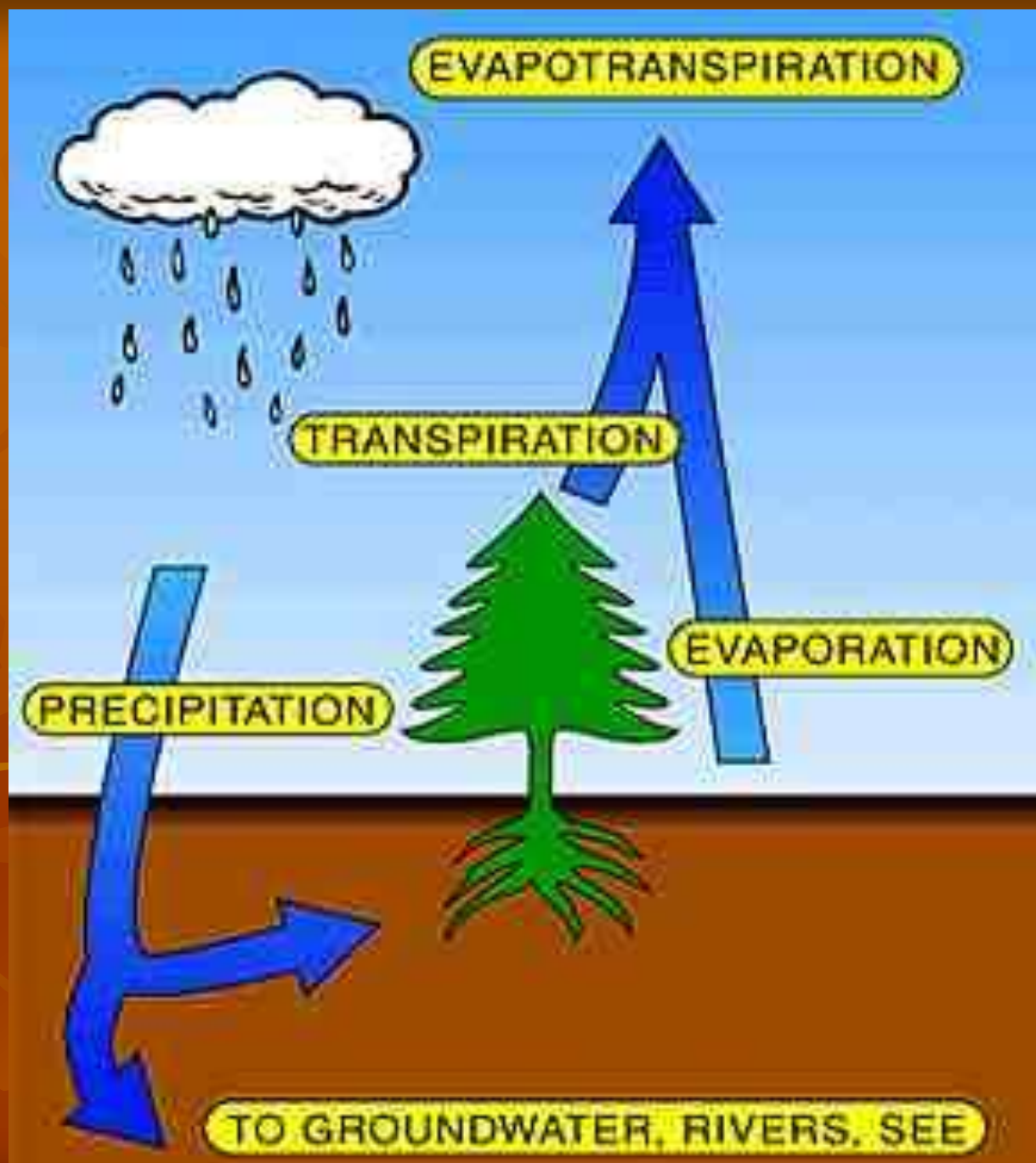
- The pressures exerted by water vapor is called the vapor pressure
- At any given temperature, there is a maximum vapor pressure that water molecules can exert.
- There can be more water vapor in warm air than in cold air
- When the maximum vapor pressure at a given temperature is reached, the air is said to be *saturated* with water vapor



Evapotranspiration



- Evaporation from land has two sources
 - Soil and other inanimate surfaces
 - Plants
- The total evaporation from both of these sources is called **evapotranspiration**



Measures of Humidity



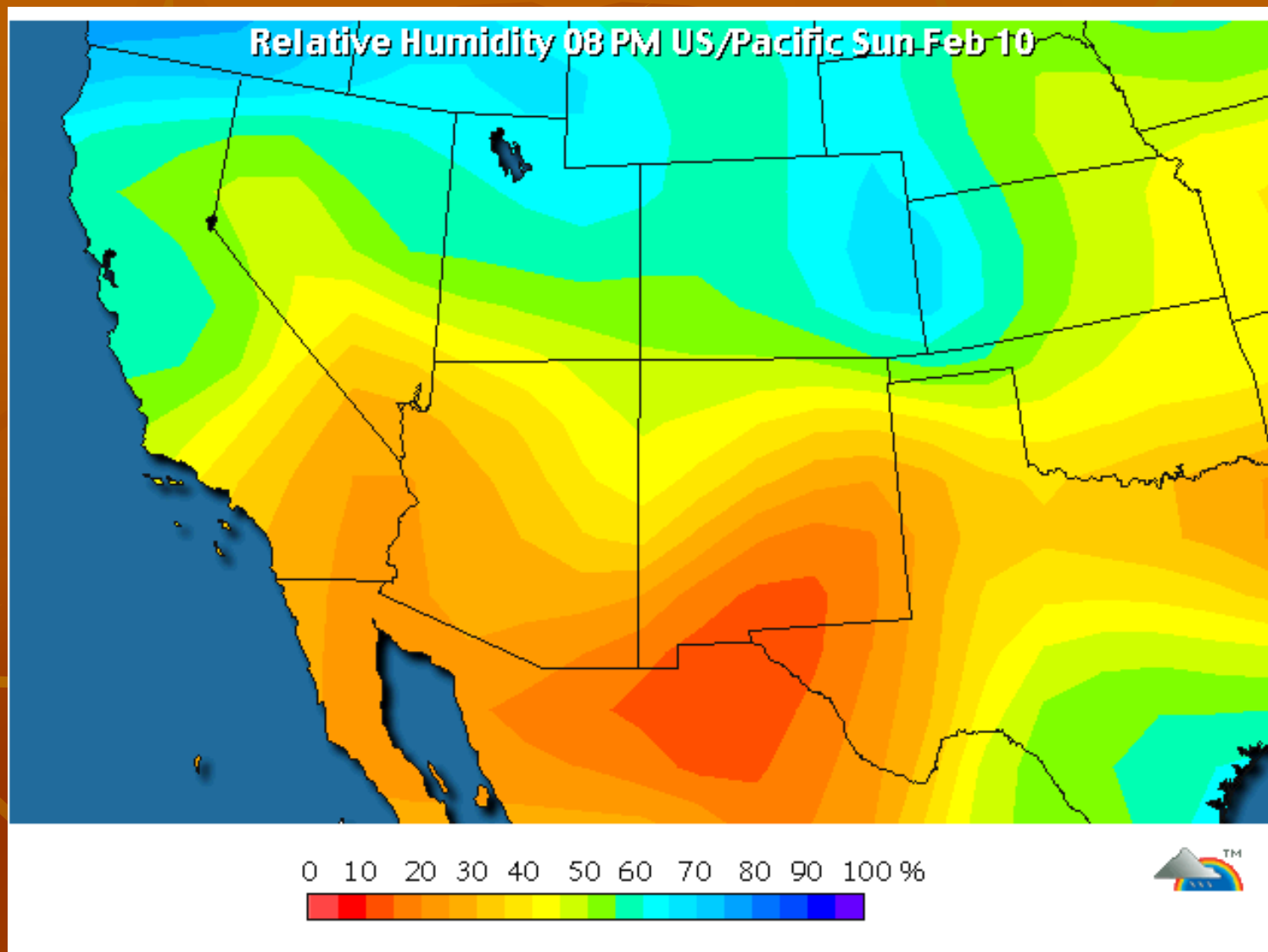
- Absolute Humidity
 - The mass of water vapor in a given volume of air
- Specific Humidity
 - The mass of water vapor in a given mass of air
- Vapor Pressure
 - The contribution of water vapor to the total pressure of the atmosphere at a given temperature

Measures of Humidity

■ Relative Humidity

- The most familiar of humidity measures
- The ratio that compares the actual amount of water vapor in the air to the water vapor capacity of the air
 - Capacity is the maximum amount of water vapor that can be in the air at a given time
 - As the temperature increases, relative humidity decreases
 - As the temperature decreases, relative humidity increases





Related Humidity Concepts



- Dew Point Temperature (or Dew Point)
 - The temperature at which saturation is reached
 - Dew Point will vary with the moisture content of the air.
- Sensible Temperature
 - The temperature as it feels to a person's body
 - Heat index, or Wind chill

Condensation

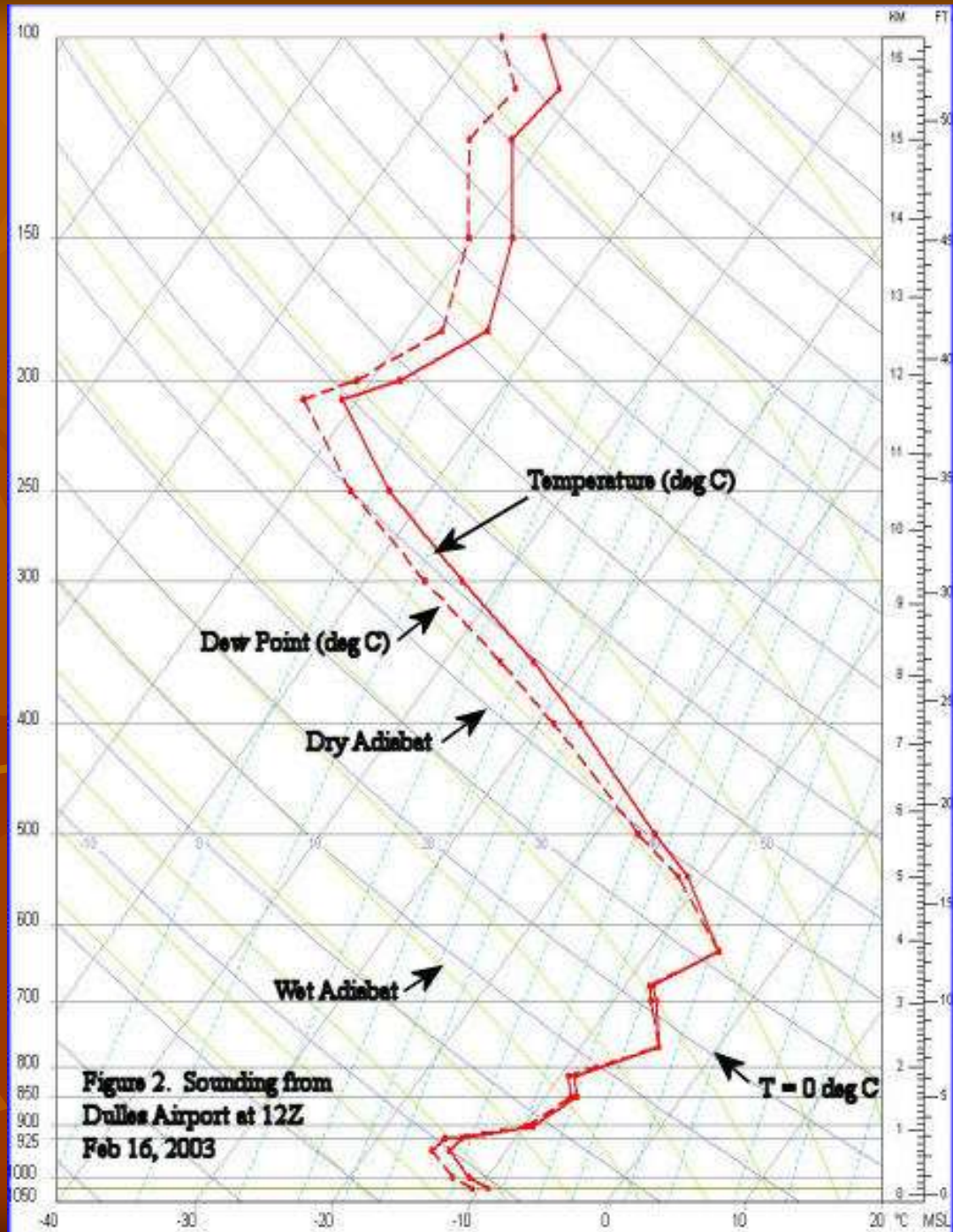


- Opposite of evaporation
- Where water vapor is converted to liquid water
 - If no surface is available no condensation will happen
 - But in the air, there usually is some surface available for condensation, even if the particles are hydroscopic
 - The beginning of a raindrop, is the condensation of water vapor on a particle

Adiabatic Processes

- As a parcel of unsaturated air rises, it cools at the relatively steady rate, 10 degrees C per 1000 meters
 - Called the Dry Adiabatic Rate
- If it rises to the dew point, it is called the lifting condensation level (LCL)
- As the condensation continues, cooling happens
 - Called the Saturated Adiabatic Rate
 - 6 degree C per 1000 meters





Clouds

- Classifications of Clouds

- Cirriform – thin and wispy and composed of ice crystals
- Stratiform – appear as a grayish sheets that cover most or all of the sky, rarely being broken up into individual cloud units
- Cumuliform – massive and rounded, usually with a flat base and limited horizontal extent but often billowing upward to great heights



Clouds

- **High**— Found 20,000 Feet, Small amount of water vapor and low temperature, and ice crystals
 - **Cirrus, cirrocumulus, cirrostratus**
- **Middle**— 6500 to 20,000 feet, composed of liquid water
 - **Alto cumulus, Altostratus**
- **Low**— 6500 feet, often appear as individual clouds, but often appear as a general overcast, somber skies and drizzly rain
 - **Stratus, Stratocumulus, Nimbostratus**
- **Vertical**— grows upward from low bases to heights of 60,000 ft., very active vertical movements, usually associated with fair weather, or storm clouds
 - **Cumulus, Cumulonimbus**





Common types of clouds in the troposphere



Cirrocumulus
(mackerel sky)
above 18,000 feet



Cirrus
above 18,000 feet



Altocumulus
6,000 to 20,000 feet



Altostratus
6,000-20,000 feet



Cumulonimbus
from near the ground
to above 50,000 feet



Stratocumulus
below 6,000 feet



Stratus
below 6,000 feet



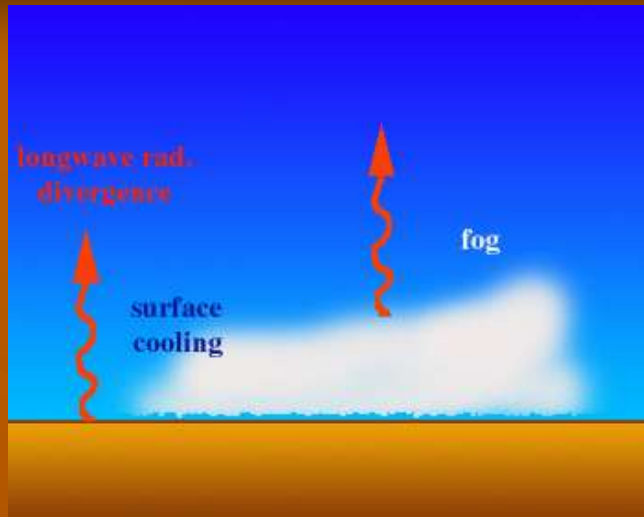
Cumulus
below 6,000 feet



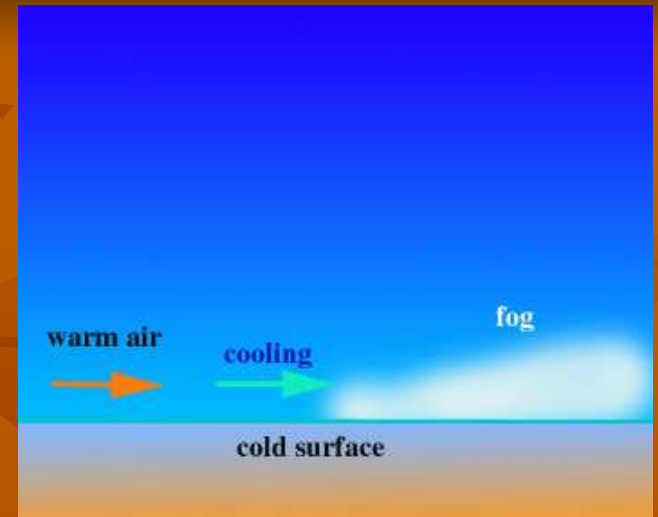
Fog

- A Cloud on the ground
 - **Radiation fog** – results when the ground loses heat through radiation usually at night.
 - **Advection fog** – develops when warm, moist air moves horizontally over a cold surface, such as snow-covered ground or cold ocean current
 - **Upslope fog or orographic fog**-- by adiabatic cooling when humid air climbs a topographic slope
 - **Evaporation fog**– results when water vapor is added to cold air that is already near saturation.

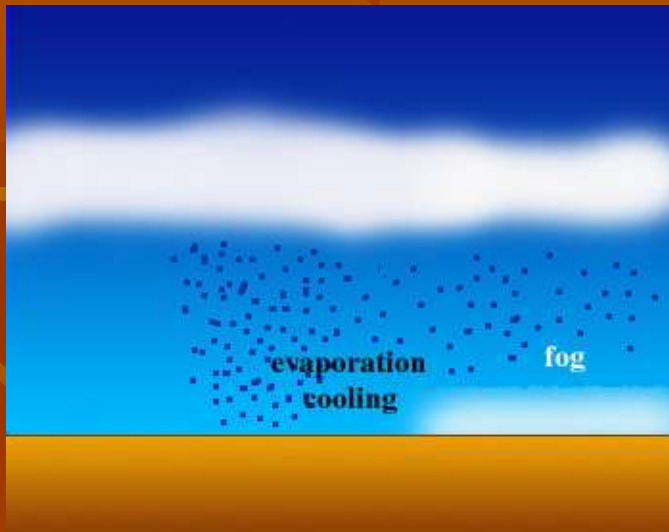




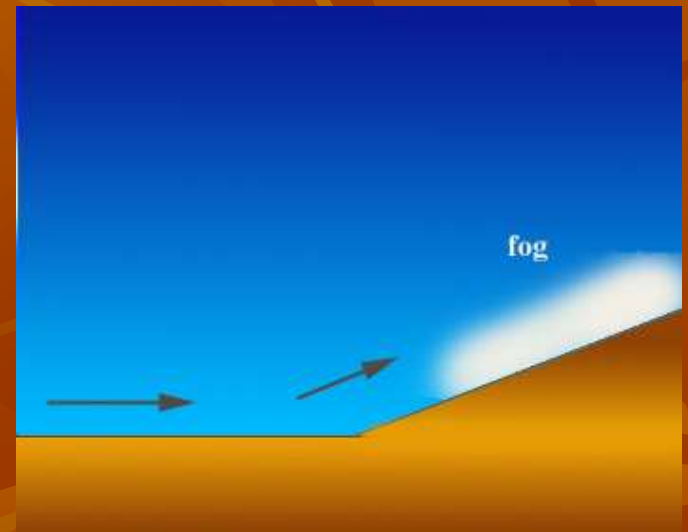
Radiation fog



Advection fog



Precipitation fog



Upslope fog

Buoyancy of Air

- Atmospheric Stability

- Stable air –if a parcel of air resists upward vertical movement
 - Could become unstable if a force is applied, such a topographical feature (mountain slope)
 - Stable air is NON-BUOYANT
- Unstable air– if it either rises without any external force other than the buoyant force or continues to rise after such an external force has ceased to function.
 - Unstable air is BUOYANT
 - Unstable air continues to rise until it reaches temperature and density equal to itself, this is called the equilibrium level.
- The intermediate condition is called Conditional Instability – between absolute stability and absolute instability



Buoyancy of Air

- **Determining Air Stability**
 - It is related to the lapse rate of the surrounding air (the environmental lapse rate)
 - Temperature and Lapse Rate
 - The temperature of the rising air can be compared with the temperature of surrounding non-rising air by a series of thermometer readings at various elevations
 - Visual Determination of Stability
 - The cloud pattern in the sky is often indicative of air stability.
 - Unstable air is associated with distinct updrafts, which are likely to produce vertical clouds



Buoyancy of Air

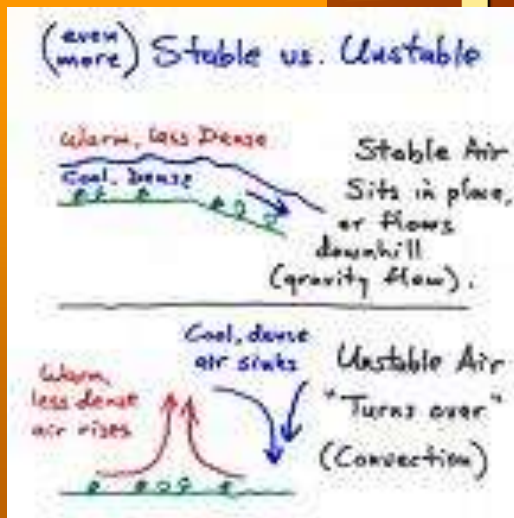
■ Characteristics of Stable and Unstable Air

■ Stable

- Non-buoyant, remains immobile unless forced to rise
- If clouds develop, tend to be stratiform or cirriform
- If precipitation occurs, tends to be drizzly

■ Unstable Air

- Buoyant: rises without outside force
- If clouds develop, tend to be cumuliform
- If precipitation occurs, tends to be showery



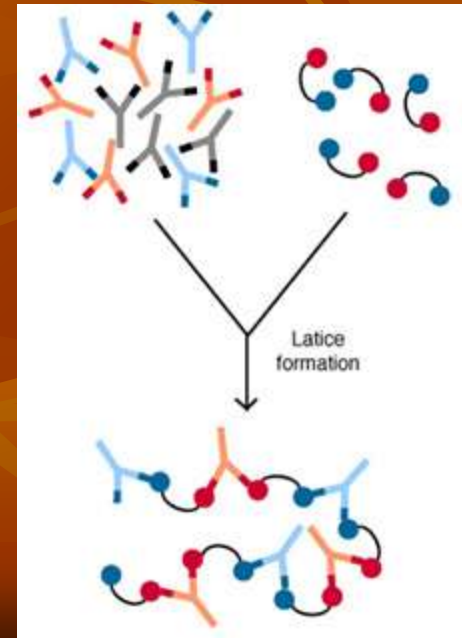
Precipitation

- All Precipitation originates in clouds, but most clouds do not yield precipitation.



The Processes of Precipitation

- Average-sized raindrop contains several million times as much water as the average-sized water droplet found in any cloud
- Two mechanisms to produce precipitation particles
 - Collision and coalescence of water droplets
 - Ice-crystal formation



The Processes of Precipitation

■ Collision/Coalescence

- The process most responsible for precipitation in the tropics, and in some middle latitudes.
- Work in “warm clouds”
- Rain is produced by the collision and coalescing.

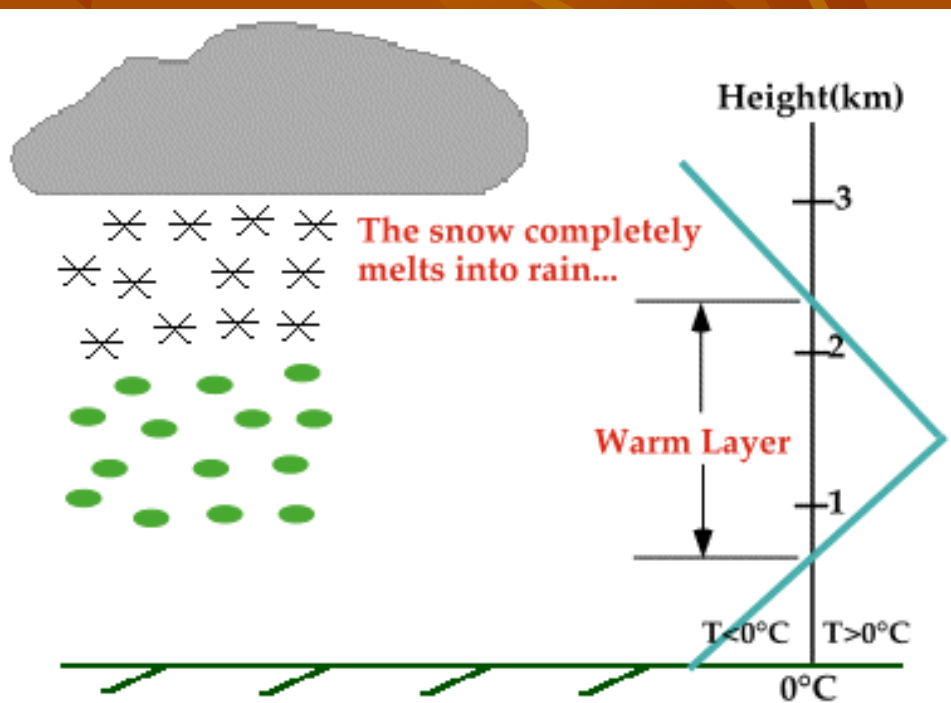
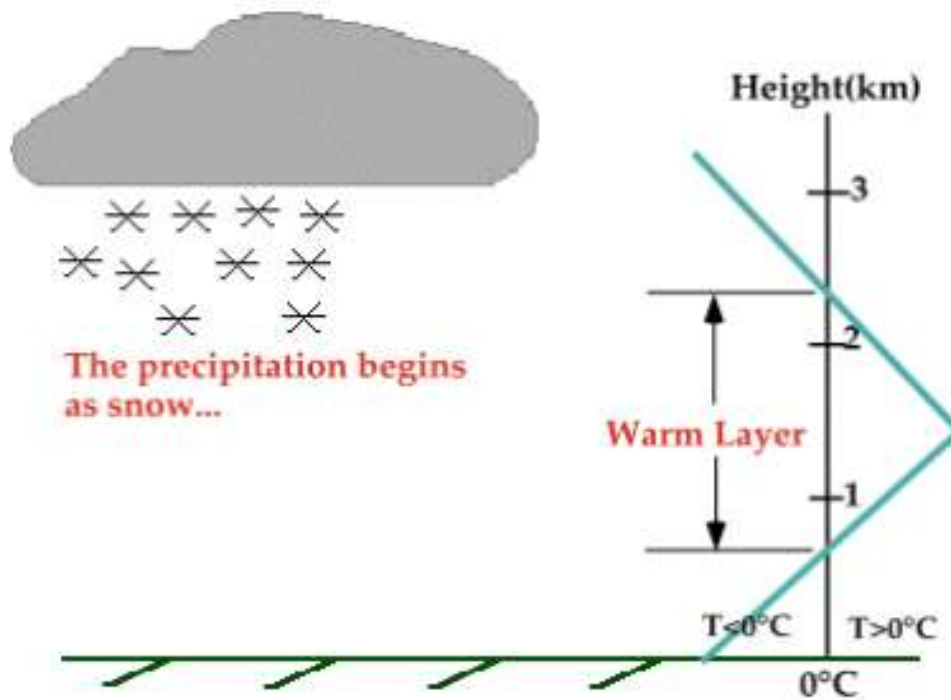


The Processes of Precipitation

■ Ice-Crystal Formation

- Clouds extend high enough to have temperatures well below the freezing point of water
 - Cold Clouds
- Clouds contain ice crystals and supercooled water droplets.
- Ice-crystals pull more water vapor to get larger
- Water droplets evaporate to replenish the water vapor
- When ice-crystals get large, they begin to fall
- As they fall into warmer air they melt, producing rain, if air is not warm they stay as snow

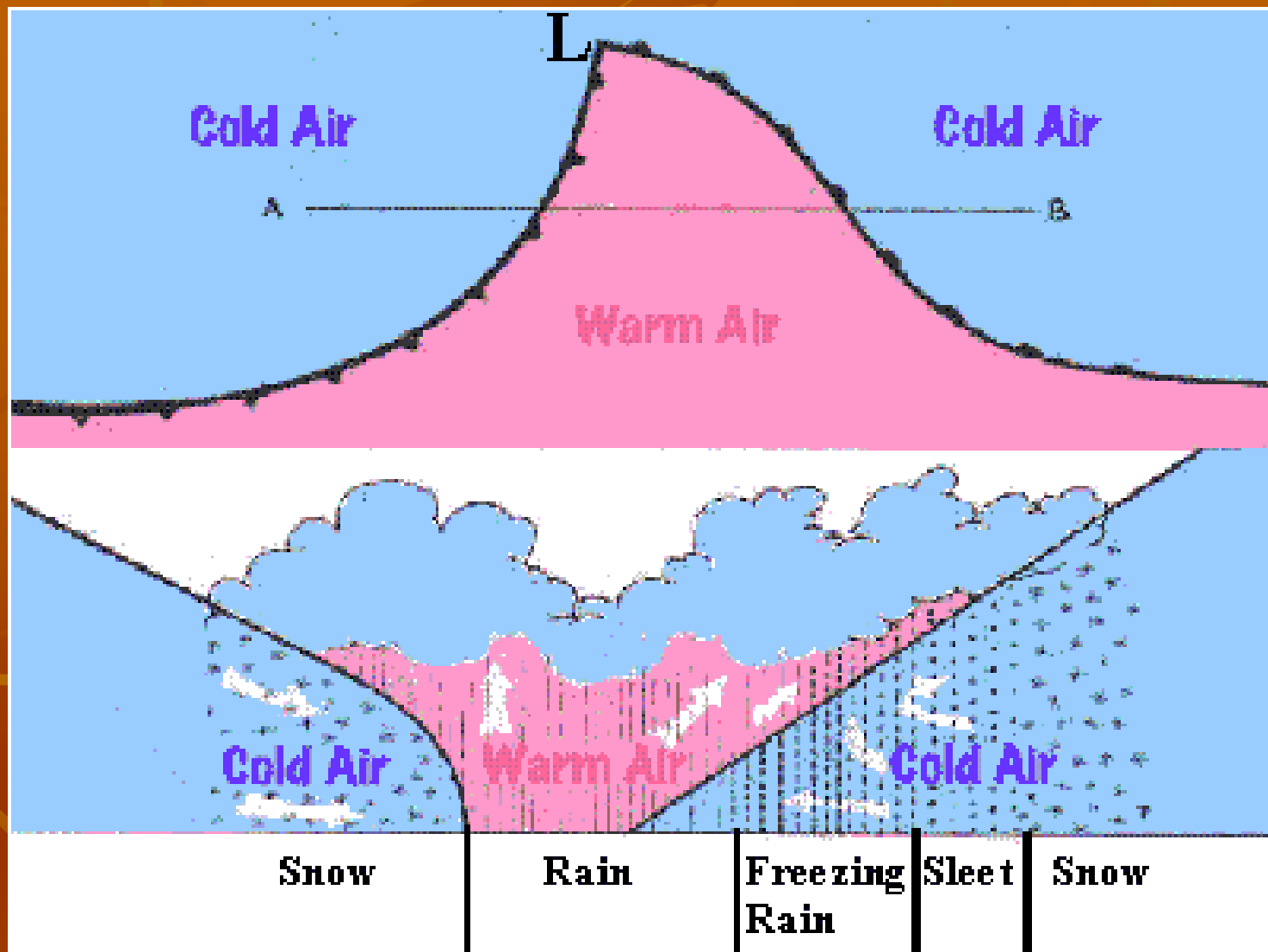




Forms of Precipitation



- **Rain**— most common form of precipitation
- **Snow**— solid precipitation in the form of ice crystals, small pellets, or flakes
- **Sleet**— small raindrops that freeze during descent and reach the ground as pellets of ice
- **Glaze** — rain that turns to ice that instant it collides with a solid object
- **Hail**— is produced in cumulonimbus clouds as a result of great instability and strong vertical air currents (updrafts and downdrafts)



Atmospheric Lifting and Precipitation



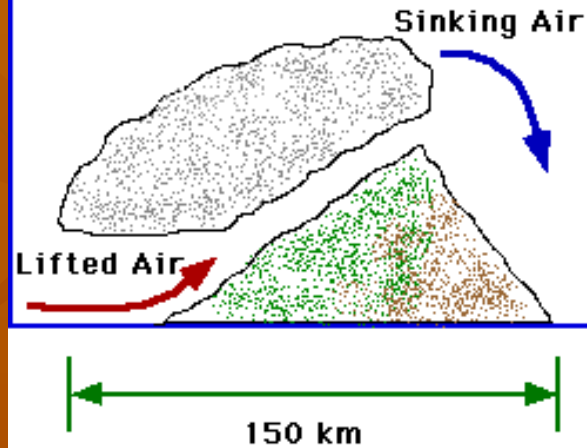
- **Convective Lifting**—the density of the heated air is reduced as the air expands, and so the parcel rises toward a lower-density layer
- **Convective precipitation**— typically shower, with large raindrops falling fast and furiously but only for a short duration.

Atmospheric Lifting and Precipitation

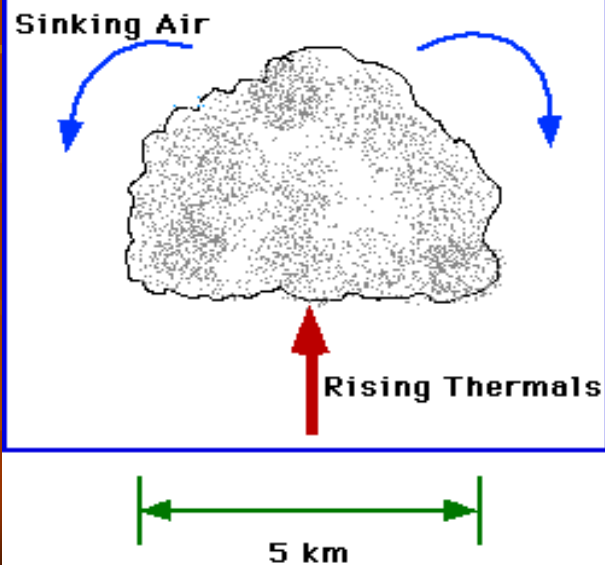


- **Topographic barriers--** that block the path of horizontal air movements are likely to cause large masses of air to travel upslope. Produces orographic precipitation, with a rain shadow
- **Frontal Lifting**— when unlike air masses meet and they don't mix. Warm air rises over the cooler air. Results in frontal precipitation.
- **Convergent Lifting** —when air converges the result is a general uplift because of crowding. Causes convergent precipitation.

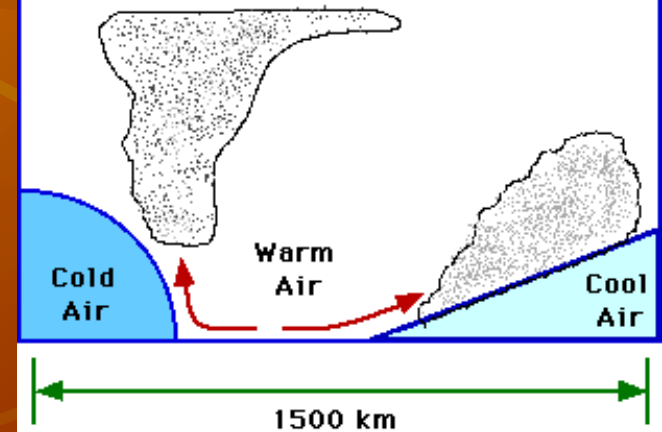
Orographic Lift



Convection



Frontal Lifting



Global Distribution of Precipitation

- Average Annual Precipitation
 - The amount of precipitation spatially found around the world.
 - Cartographically shown by isohyet.
 - Four principal regions of precipitation
 - Tropical latitudes (wettest areas, easterly trade winds, heavy rainfall)
 - Dry lands on the western sides of continents in subtropical latitudes (dominated by high-pressure)
 - Dry lands in the mid latitudes are most extensive in central and southwestern South America
 - High Latitudes, not much precipitation anywhere,. Water surfaces are scarce and cold, and little opportunity exists for moisture to evaporate into the air.



Seasonal Precipitation Patterns

- Prominent generalizations that can be derived from maps includes the following:
 - Seasonal shifting of major pressure and wind systems, following the sun, is mirrored in the displacement of the wet and dry zones
 - Summer is the time of maximum precipitation over most of the world. Exceptions occur in relatively narrow zones along western coasts between 35 degrees and 60 degrees latitude, in both the northern and southern hemispheres.
 - Most conspicuous variation in seasonal precipitation is found, predictably, in monsoon regions, where summer tends to be very wet and winter is generally dry.



Precipitation Variability



- Precipitation variability- the expected departure from an average precipitation in any given year, expressed as a percentage above or below average.

Acid Rain



- Acid Rain – deposition of either wet or dry acidic materials from the atmosphere on Earth's surface.
 - Sulfuric and nitric acids are the principal materials recognized so far.
 - Clean rain fall has about a 5.6 Ph value of acidity.
 - The lower the Ph value of a liquid the more acidic it is.

Acid Rain



- Damage from acid rain
 - Major hazard to the environment
 - The kills the plants and fish
 - Destroys buildings (ancient and modern)
 - Harmful to all living things
 - Moves downwind causing damage
 - 1990 Clean Air Act Amendments creating the Acid Rain Program
 - 1991 Canada and United State signed the Air Quality Agreement to reduce Acid Rain.